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THE FISH RESOURCES OF THE BALTIC SEA

by

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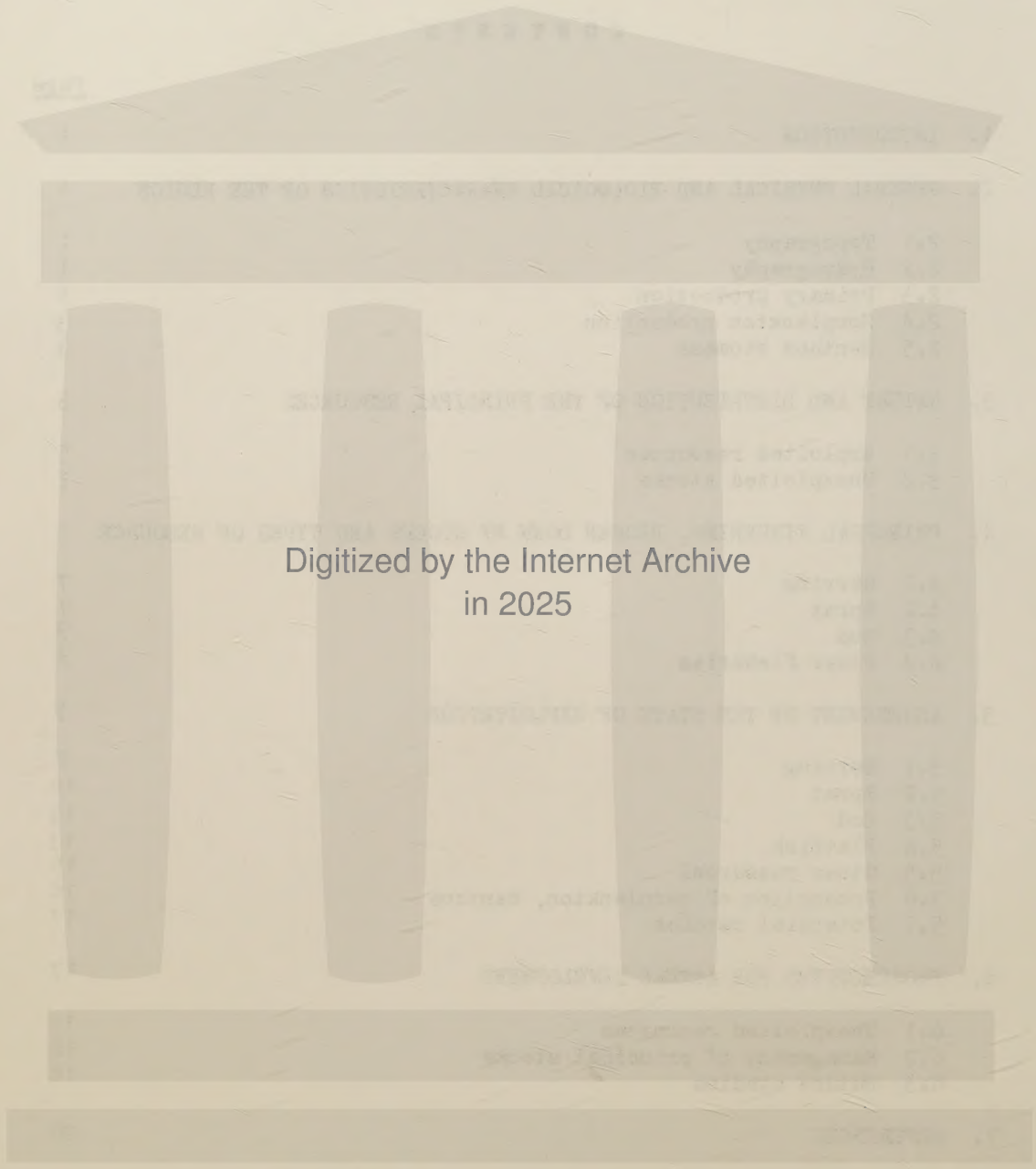

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1. INTRODUCTION

The area covered by this review is the same as the area of responsibility of the International Baltic Sea Fishery Commission (IBSFC). This was established in October 1974, following the signing of a Convention on Fishing and Conservation of the Living Resources in the Baltic Sea and the Belts in September 1973 by all the countries bordering the Baltic (Denmark, Finland, German Democratic Republic, Federal Republic of Germany, Poland, Sweden and U.S.S.R.). The area is the same as the divisions IIIb, c and d of the International Council for the Exploration of the Sea (ICES). Finer sub-divisions (numbers 22-32) have since been defined (see Fig. 1). Sub-divisions 22 and 23 correspond to the ICES divisions IIIb and IIIc. The total area is a little under 400 000 km^2.

In January 1978, the German Democratic Republic, Poland and Sweden extended their fisheries jurisdiction to median lines. The other countries are expected to do so shortly.

2. GENERAL PHYSICAL AND BIOLOGICAL CHARACTERISTICS OF THE REGION

2.1 Topography

The Baltic came into being by melting of the ice only some 14 000 years ago. Its sediment layer is small in comparison to the North Sea. This fjordlike inland sea has a narrow and shallow entrance (threshold 18 m). Ridges divide the area into several basins, where maximum depths range from 50 to 300 m. The average depth is about 55 m.

2.2 Hydrography

Water temperature ranges from 0° to 18°C on the surface. It is rather constant at some 5°C in bottom layers. The inner parts and the coastal areas of the Gulfs of Bothnia, Finland and Riga are ice-covered from January through May. There is a drastic decline of the salinity from > 20‰ (surface) and > 30‰ (bottom) in the Belt Sea to some 2‰ in the northern and northeastern gulf areas.

The water budget shows a surplus of freshwater owing to the discharge by rivers which results in a surface outflow of light water. Differences in density and hence hydrostatic pressure between the North Sea and the Baltic produce an inflow of water of high salinity along the bottom. This leads to an extraordinary stable halocline which prevents mixture of top and bottom water layers. Breakdown of organic matter reduces the oxygen content near the bottom. Hydrogen sulphide is produced if no influx of oxygenated water occurs. Such an inflow, however, reinforces the stability of stratification unless it is very strong and persistent.

During rare periods of strong and persistent westerly winds, a large and steady inflow of saline water is established which carries across the entire Baltic along the bottom, flushing the deep basins and finally producing an upwelling of moderately saline, nutrient-rich water as the bottom current reaches the shallows of the easternmost Baltic and finally turns west at the surface. Because of the upwelling, these strong inflows temporarily increase primary production in the eastern Baltic, but their most important effect is flushing and reoxygenating the deep basins. Inflows of this nature occurred at the beginning of the century, near the beginning of the twenties, in 1937, probably in 1948, in 1951 (Fonselius, 1962) and in 1975. Salinity and temperature seem to have been higher during recent decades than before, while oxygen values show an opposite trend (Fonselius, 1970).

Floating of cod eggs occurs only in a salinity of not much less than 10‰. Influx of saline water increases the volume of water suitable for keeping the eggs afloat, and provides a sufficient ventilation. Decrease in oxygen will eventually prevent spawning of cod and flatfish on the bottom. It may finally destroy the bottom fauna. Cod is then forced to concentrate in dense aggregations off the bottom which enables high catches by pelagic trawls.

2.3 Primary production

Data on primary production published by several authors are not strictly comparable. Firstly, phytoplankton blooms occurred five to nine times a year in Kiel Bay (v. Brŏckel,

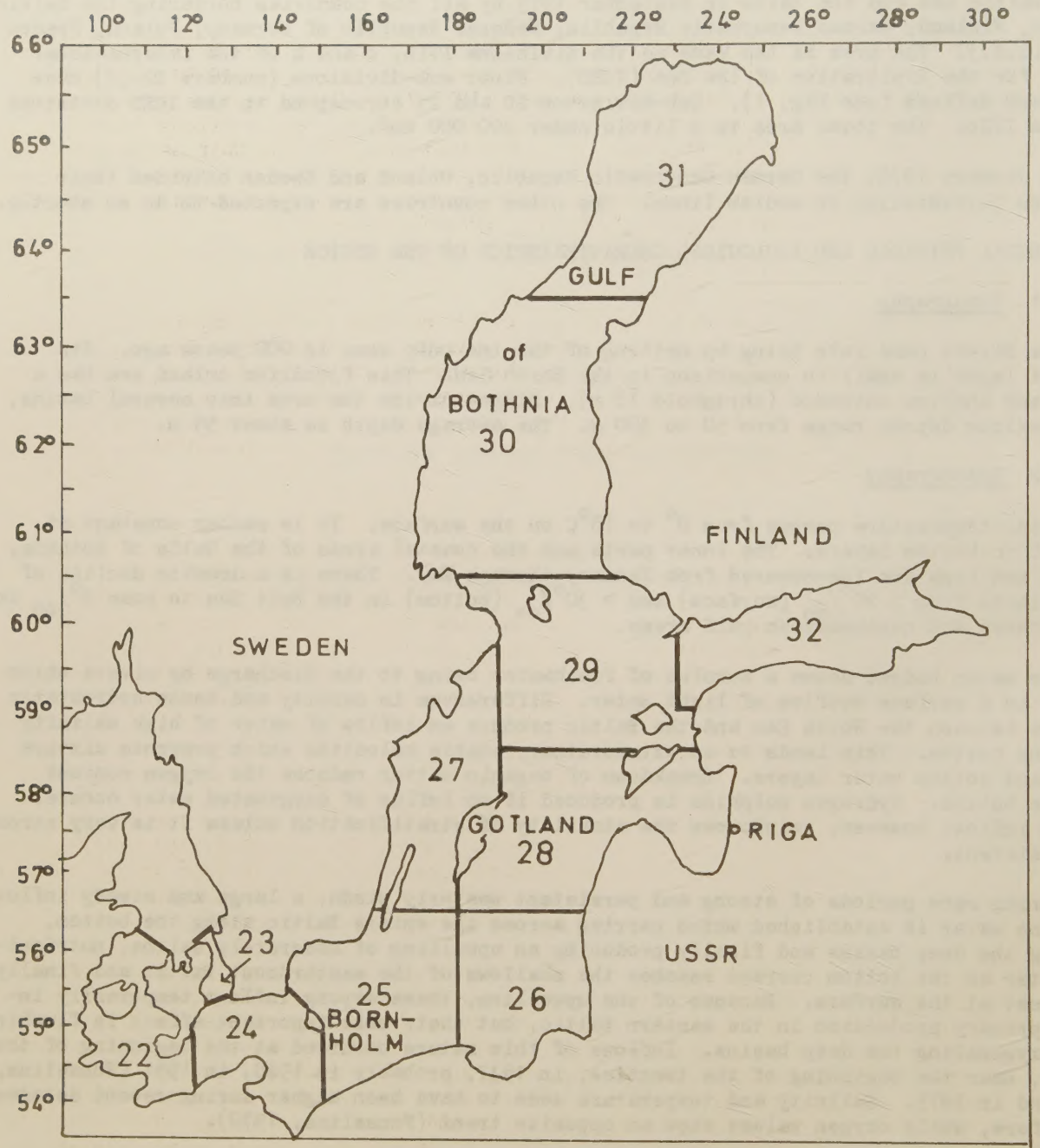

Figure 1: The Baltic Sea

1975). A rather high frequency of sampling in time is, therefore, necessary. Secondly, production estimates tend to increase with a decrease in duration of incubation. Thirdly, for estimating total production results from offshore stations are relatively more important than those from inshore sites and the number of offshore stations was low in all investigations, as was the total number of stations. This may partly be counterbalanced by high frequencies of sampling in time.

Taking these difficulties into consideration reasonable values have been selected to assess total production (Table 1). These are published by v. Bodungen (1975) for the Belt Sea. He sampled one station 29 to 37 times a year (1972-74). Other regions were covered by Ackefors and Lindahl (1975) and Lindahl (1977). They sampled four stations four to eighteen times a year (1973-75). No useful data are available for the Gulf of Finland. Since this area is relatively small production there was assumed to equal the weighted mean of the other areas. Total primary production in the Baltic is then estimated at 40 million tons carbon per year, equivalent to a little over 100 $gC/m^2/year$.

2.4 Zooplankton production

Martens (1976) sampled zooplankton 37 times at one station in Kiel Bay in 1973. He made independent assessments of population growth, grazing and mortality. The estimated zooplankton production was 17.2 to 50.5 $gCm^{-2}y^{-1}$ for the secondary level and 3.7 to 5.2 for the tertiary level, depending on Oithona similis being either herbivorous or carnivorous. Martens concluded from published information that omnivorous feeding behaviour was most likely for this species and suggested 33.8 and 5.2 $gCm^{-2}y^{-1}$ of secondary and tertiary zooplankton production, respectively.

Five years of sampling at three to seven offshore stations in the Baltic proper four to twenty-four times a year led to preliminary estimates of 10 and 20 $gCm^{-2}y^{-1}$ for the Gotland basin and the southern Baltic (Hernroth and Ackefors, 1977). This is higher than earlier values, 5 to 8 $gCm^{-1}y^{-1}$, (Ackefors and Hernroth, 1975; Lindahl, 1977). The production for the Gulf of Bothnia was estimated on the assumption that the transfer efficiency was the same as the average for the Gotland basin and the southern Baltic weighted according to the size of the regions. From the weighted mean production per unit area for five of the six regions the total zooplankton production is found to be 5.54 millions tons of carbon per year. (Table 1, column 3).

2.5 Benthos biomass

Previous data on benthos density covering the period up to 1957 are no longer valid (Demel and Mulicki, 1954; Zenkievitch, 1963). Shurin (1964), Zmudzinski (1969) and Leppäkoski (1975) have shown that the bottom fauna of the Baltic proper vanished in 1958 at depths below 70 to 80 m after a period of stagnation and subsequent production of hydrogen sulphide. There was a quick recovery but only to densities less than half the former.

The fauna had changed from arctic-boreal to short-lived cosmopolitan species, mainly polychaetes. No molluscs repopulated the deeper areas as several periods with abiotic conditions followed subsequently. The most recent estimates of densities are shown in Table 1, based on data from Arntz (1971), Bagge (1973), Leppäkoski (1975), Shurin (1964), Zmudzinski (1969). The chances are, however, that in any particular year there will be no bottom fauna at all at depths below, say, 80 m. The fauna in the shallower reaches seems to be unaffected. It largely consists of Macoma baltica, Mytilus edulis and Cyprina islandica. The latter is important in the Belt Sea, where Arntz (1971) found 570 gm^{-2}. This value is not listed in Table 1. The total biomass of benthos in the Baltic is estimated to be 9.6 million tons, excluding Cyprina islandica in the Belt Sea.

3. NATURE AND DISTRIBUTION OF THE PRINCIPAL RESOURCES

Some 100 species of fish have been reported from the Baltic. Roughly two thirds of these are either rare fishes or visitors. The number of species diminishes from south to north, and the composition changes as well. In particular, the proportion of freshwater species increases. These stay mainly in coastal areas.

Growth is slow in the northern parts and the maximum size attained there is smaller than in southern regions.

Table 1

Plankton production, biomass of benthos, and approximate distribution of fish catches in the Baltic as estimated during 1972-1976

Region	Area $km^2 \times 10^{-3}$	Prim. prod. $gC\ m^{-2}y^{-1}$	Zoo-plankton prod. $gCm^{-2}y^{-1}$	Benthos density gm^{-2}	Catch/unit area $gm^{-2}y^{-1}$		Ratio Pel./Dem.	Catch tons $\times 10^{-3}$			
					Dem.	Pel.		Total	Herring	Sprat	Cod
Bothnia Bay	32	71	(9)[a]	1	0.1	0.3	3.0	49	6		
Bothnia Sea	83	81	(10)[a]	41					22	Ø	
Gulf of Finland	30			27	0.3	2.8	9.3	93	37	40	
Gotland Basin	134	101	10	8	0.2	1.5	7.5	229	127	70	12
South Baltic	94	119	20	26	1.8	3.1	1.7	464	184	95	155
Belt Sea	20	158	39	93	2.3	1.8	0.8	81	23	5	33
Weighted mean		101.6	14.1	24.5	0.7	1.7	2.4				
Total, tons $\times 10^{-6}$		39.9	5.54	9.6	0.27	0.65		0.92	0.40	0.21	0.20

a/ Calculated from primary production assuming transfer efficiency equal to weighted mean of values for Gotland Basin and the southern Baltic.

3.1 Exploited resources

Sprat, herring and cod contribute almost 90% of the total catch and some 80% to the market value. Corresponding figures for eel and salmon are less than 1% and 10%, respectively (Table 2). The ratio of the catch of pelagic to demersal species decreases from north to south. The catch per unit area is low in the Gulf of Bothnia and, for demersal fish, also low in the Gulf of Finland and in the Gotland basin (Table 1).

Nikolski (1957) discriminates two subspecies each for herring, sprat and cod. These are separated by a zoogeographical border roughly coinciding with the border between subdivisions 24 and 25 (Otterlind, 1962).

Both autumn- and spring-spawning herring occur throughout the Baltic. Spring herring spawn along almost the whole coast in bays and in the skerries, the most important areas being the southwestern coast of Finland, the stretches near the Estonian islands, the Swedish coast of the Baltic proper and the island of Rügen (GDR). Younger fish of the latter population have been shown to feed in the Baltic whereas a number of older specimens were recorded in the Kattegat/Skagerrak area (Biester et al., 1976). Autumn spawners appeared to be less important since the beginning of the seventies.

Between its first and fifth year herring grows from about 13 to about 25 cm in the southern Baltic, and from about 9 to about 17 cm in northern waters. Growth parameters have been reported to differ between regions. It has, however, not been possible so far to assess the degree of interchange. The ICES Working Group on Assessment of Pelagic Stocks in the Baltic (Pelagic Working Group) has, therefore, dealt with four management units the areas of which are subdivisions 22-24, 25-29, 30-31 and 32 (Pelagic Working Group, 1977).

Sprat is found all over the Baltic. However, it is very rare in the Gulf of Bothnia. During winter sprat keeps close to the bottom in coastal areas but dense aggregations are also found in deep water layers east and north of Gotland. Between the first and the fifth year sprat grows from about 9 to about 13 cm.

On the basis of measurements of a number of characters Elwertowski (1960), Veldre and Hell (1961) and Polivaiko (1976) all distinguished several populations. However, significant differences were not shown to exist and the available data do not permit a rigid statistical treatment. There is much mingling during spring and summer in the southern Baltic. Differences in growth and probably in mortality led the Pelagic Working Group (1977) to consider three units confined to firstly subdivisions 24 and 25, secondly to 26 and 28, and thirdly to 27, 29 and 32.

Salmon and smelt are the other pelagic fish of some commercial importance. Salmon feeding in the Gulf of Bothnia and in the Baltic proper are recruited from rivers running into the former area. Populations in the Gulf of Finland and in the Gulf of Riga are separate from the main stock. More than one third of the salmon caught today are hatchery reared. Smelts stay near the coast.

Except for the inner regions of the gulfs cod is spread throughout the area with the density gradually decreasing in northern areas. The main spawning place is the Bornholm basin and, at periods with good airing in bottom water layers, the southeastern part of the Gotland basin is also an important locality for reproduction. Tagging experiments have confirmed that the two recognized subspecies form separate stocks in the Belt Sea and in the subdivisions eas of Bornholm. For assessment purposes cod in the Arkona basin (subdivision 24) is also treated separately by the ICES Working Group on Assessment of Demersal Stocks in the Baltic (Demersal Working Group, 1977).

Among flatfish, which contribute about 2% to the total catch, dab and plaice are important in the Belt Sea. Flounder yields the highest flatfish catches and prevails in the Baltic proper (subdivisions 24-29). Limited migrations were shown by tagging experiments. The spawning populations in each of the subdivisions 22-28 were, therefore treated as unit stocks (Demersal Working Group, 1974).

Table 2

Approximate weight and value (1973) of landings

Species	weight tons x 10^{-3}	%	value $ x 10^{-6}	%
Herring	400	43	130	36
Sprat	200	22	80	23
Cod	200	22	80	22
Flatfish	22	2	10	3
Eel	4	<1	20	6
Salmon	3		15	4
Others	91	10	20	6
Total	920		355	

Table 3

Composition of R.V. catches, March-May 1969-72, 1975, in subdivisions 24-26, raised to the level of annual cod catches taken in the southern Baltic, in tons (Thurow and Tiews, unpublished)

Cod	Whiting	Rockling	Flounder	Plaice	Others
155 000	383	609	24 608	920	88

Whiting is of limited importance in the Belt Sea. The mussel (Mytilus) is also harvested there.

Lampreys, vendace, pike, cyprinids, garpike, sandeel, burbot, pikeperch and ruff are all exploited but not separately listed in the Bulletin Statistique. A species breakdown of catches for some of the demersal percomorphs was recently published for the first time. ICES has kindly supplied data for additional years in advance of publication. It appears that eel-pout, stickleback and Atlantic gobies are exploited. These are species confined to coastal grounds of the whole Baltic.

3.2 Unexploited stocks

Trawling surveys in spring 1969-71 and 1975 between the Arkona and the Gotland basins, in depths of 45 to 130 m, indicated that rockling contributes as much as 0.5% to the weight of the total catch (Thurow and Tiews, unpublished). Density seems to be highest in shallow muddy grounds. All other unexploited species found contributed less than 0.5% to the total weight of the catch (Table 3). Experimental trawling in the Askö area (subdivision 27) at depths of 20 to 25 m revealed that, after herring, eel-pout and fourhorned sculpin were frequent (Aneer, 1975).

4. PRINCIPAL FISHERIES, BROKEN DOWN BY STOCKS AND TYPES OF RESOURCE

International catch statistics are available from the beginning of the 19th century but these data are not very reliable. It is likely, however, that the total catches did not exceed 100 000 tons. The fishery was entirely restricted to inshore areas. After the first world war motorized cutters extended their fishing with otter trawls to offshore grounds. The main object of the fishery until the thirties was flatfish since the vessels were slow. Pair trawling had started by then, and catches of herring, sprat and cod gradually increased. The southern Gotland basin was first visited in the thirties.

All Baltic countries, except Finland, are largely engaged in fisheries outside the Baltic. In particular, effort is shifted between the Baltic and the North Sea at times.

4.1 Herring

Pair trawling by bottom trawl was important until the beginning of the sixties when the pelagic gear was introduced. Trap nets and set nets are also important elements of the fishery for spring spawners.

Catches rose from some 70 000 to 200 000 tons in the early fifties which is thought to have resulted simply from an increase in pair-trawling effort. Introduction of the mid-water trawl led to a further steep rise at the end of the sixties when over 300 000 tons were landed. The present level of 400 000 tons was reached in 1973 (Table 4). For the time being the U.S.S.R. takes 30% of the catches. Finland, the GDR, Poland and Sweden each contribute some 16%. About 6% is the share of Denmark and the FRG. Nearly 50% of the herring catches are taken in the southern Baltic (subdivisions 24-26) and almost 80% in the Baltic proper (subdivisions 24-29).

North Sea vessels have recently been fishing in the Baltic for industrial purposes. Their effort and their catch was not recorded. Otherwise little of the catch is said to be used for fishmeal production.

4.2 Sprat

Until the fifties sprat was fished close to the coast with seines, gill nets and bottom trawls. Around the mid-fifties the midwater trawl was introduced which led to an enormous increase in landings from some 20 000 tons in 1957 to about 100 000 tons in 1964. Five years later the yield rose again and had doubled by 1972 when 200 000 tons were caught (Table 4). This level was reached and maintained by fleet fishing with motherships. It has also resulted in part from fishing on shoals of sprat which were not exploited before, their average age having been 6.4 years (!) (Rechlin, 1967).

Table 4

Catch and potentials in the Baltic, ICES Divisions IIIb, c, d tons x 10^{-3}

Species	1958/62	1963/67	1968/72	1971	1972	1973	1974	1975	1976	POTENTIAL
Bream	2				1	1	1	1		
Pike	2				1	2	2	2		
Pikeperch	2				Ø	1	1	1		
Perch					1	2	3	3		25
Roach							1	1		
Burbot						1	Ø	1		
Other freshwat. fishes	12	17	17	14	14	16	14	11		
Eel	4	5	4	4	4	4	4	4	3	4
Salmon	3	3	3	2	2	3	3	3	3	
Smelt	6	6	7	8	2	6	5	6	5	
Vendace					1	1	2	2		15
Pollan					2	2	3	3		
Other Salmonids	2	3	5	3	6	2	Ø	Ø		
Dab	1	1	1	1	2	2	2	2	2	3
Flounder	8	12	13	12	14	14	12	12	13	22
Plaice	5	6	5	4	3	6	4	4	4	5
Cod	151	164	196	164	192	194	192	236	249	225
Whiting	2	2	1	1	1	2	3	2	4	2
Rockling	Ø									2
Sand-eel										20
Eel-pout					11	14	19	13		35
Atlantic Gobies					2	2	2	2		30
Sticklebacks						5	6	9		30
Other Demersals		3	9	15	Ø	Ø	Ø	1		5
Garfish	1	1	1	1	1	1	1	1	1	5
Herring	178	251	333	339	346	404	397	409	396	400
Sprat	43	82	152	184	209	210	243	208	199	200
Unsorted fishes	27	14	22	24	24	27	21	28	28	25
Mussel	1	4	4	6	5	5	5	5	8	5
Total, without GDR	449	521	691	706	750	820	844	869		
Total, GDR incl.				781	860	921	945	974		1058

Figures for herring, sprat, cod, flounder from 1963 onwards from working group reports, all others from BULL.STAT. Except for herring, sprat, cod, flounder, GDR not included in breakdown to species until (and incl.) 1972. Ø -less than half the unit, blank - no information.

Forty-five percent of the landings have been obtained in the southern Baltic (subdivisions 24-26) and over 75% in the Baltic proper (subdivisions 24-29). Almost no catches were taken in the Gulf of Bothnia.

The U.S.S.R. and Poland accounted for 58% and 28%, respectively, of the landings.

4.3 Cod

Cod was virtually unexploited until the mid-thirties when the landings hardly reached 10 000 tons. A fleet of German steamers started fishing in 1939 and a peak catch of 81 000 tons was obtained in 1943. There is some evidence of an enormous increase in effort during the first few years after the war (Thurow, 1974). The catches fluctuated about a level of some 160 000 tons between 1951 and 1966. A further increase ultimately led to 250 000 tons in 1976 (Table 4).

The otter trawl has been the main gear for a long time. In recent periods with a deficit of oxygen in bottom water layers this has been largely replaced by the pelagic pair trawl, but the otter trawl has also been improved by the application of bobbins which permit fishing on rough grounds. Old cod were at once caught in great numbers. Net drums were introduced quite recently.

Catch/effort data are scarce and inconsistent. But effective effort is believed to have increased because of stronger engines and the new equipment mentioned.

Denmark and Poland have a share of some 30% each in the total catches. The share of the U.S.S.R. is 20%. Almost 80% of the cod landed are taken in the southern Baltic.

4.4 Other fisheries

Flatfish are mostly taken in bottom trawling for cod, and the catches have followed those of cod, the present level being some 25 000 tons. The big shares are Denmark 28%, Poland 24%, German Democratic Republic 19%.

Eel is mainly exploited on its spawning migration in pound nets. The greatest proportion of the catch is taken in the Belt Sea and along the southern coast of Sweden. Hence, Denmark lands some 55% of the total, Sweden 20%.

An offshore fishery on feeding salmon by means of drift nets and longlines developed after the war. This gear is the main element in salmon exploitation, its share being some 75%. Denmark, Finland and Sweden take 40%, 25% and 20%, respectively. Almost nothing has been published about fishing for other species.

5. ASSESSMENT OF THE STATE OF EXPLOITATION

5.1 Herring

The Pelagic Working Group has presented four reports (1974-77). There are some relevant papers by individual scientists which were reviewed by the working group. The state of exploitation was depicted in the 1974 and 1975 reports which together covered all subdivisions but 26 and 27. The conclusion was (1974) that in all fisheries analysed, exploitation had either approached or exceeded $F_{0.1}$. An increase in age at first capture could produce some gain in yield.

However, basic data have not been available to the group. The results of analyses were presented by individual experts instead. Their mortality estimates are based on samples taken during a number of years prior to 1973 when the yield was lower than 350 000 tons and in some instances possibly less than 300 000 tons.

In its 1977 report the working group produced yield curves for subdivisions 22-24 and 29-31, representing some 35% of the total catch. These revealed that little gain in yield can be expected from a considerable increase in effort. It is important in this context to

be aware that an unknown part of the Rügen herring (total catch, some 40,000 tons) spawning in subdivision 24 feeds outside the Baltic.

The working group (1977) used VPA to evaluate fishing mortalities for the major stocks and found F to increase from 0.3 to 0.8 from north to south. These values are all much lower than the ones estimated earlier from catch/effort and/or age composition (0.5-1.6).

The basic data revealed some inconsistencies, in particular for subdivisions 25-29. The year-classes 1968 and, less so, 1969 do not show a general decline in numbers caught per age from 1971 through 1976. A corresponding increase in fishing effort could be the explanation. This is, however, not so since the phenomenon is not shown by the other year-classes. Also, growth parameters vary widely and no measures of reliability are available. It is, therefore, suggested that improved sampling might permit better assessments.

The data provided by the working group so far do not permit a sound assessment of potential. They do suggest, however, that the stocks are fully exploited and that little gain can be expected from a change in effort. The potential may, therefore, be 400×10^3 tons, i.e. the present catch.

An independent estimate of the exploitation rate, $E = F/Z$ is possible from yield and production. Lishev and Uzars (1967), Zalachowski *et al.*, (1976), Strzyzewska (1962), Arntz (1973) have analysed the food composition of cod over its whole area. Zalachowski *et al.*, have also evaluated the consumption rate as a function of size. This information together with the yields and mortalities shown in Table 5 permit an estimate of the losses caused by cod in the exploited phase, i.e. 343×10^3 tons of herring (Table 6). Lishev and Uzars (1967) have reported on the size distribution of the herring preyed upon by cod. It appears that some 30% in number are of sizes which enter the catches. Data of the Pelagic Working Group (1977) indicate that their share of the total weight consumed may be some 60%. Losses caused by predation of cod on herring in the exploited state would, therefore, amount to 206×10^3 tons. The removal from the exploited herring stock, including the catches, is thus more than 600×10^3 tons. This is an underestimate of the production of the exploited herring population, and the exploitation rate $F/Z = Y/P = 0.66$ is an overestimate since there are losses in addition to those caused by cod and by the fishery. $F/Z = 0.72$ as calculated from working group data (Table 5) is even higher. We may also consider that Beverton (1963), from age data, found $Z = 0.45$ for the southern Baltic. At the period in question (1939-45) the yield was 50 to 80 000 tons so that $M < F$. Ursin's formula (1967), $M = \bar{w}^{-1/3}$, yields 0.26; 0.29; 0.39 for M, south to north. Since predators are scarce in the north an overall $M \approx 0.3$ is assumed ($M = 0.21$ from working group values, weighted according to catch). These values of M and F/Z do not appear to change the earlier conclusions since the yield function tables suggest that the fishery is near the maximum.

5.2 Sprat

Papers by individual experts dealing with the present status of the fishery have been reviewed by the Pelagic Working Group. Yield curves in the first report of the Pelagic Working Group (1974) show fishing to be far below $F_{0.1}$. Since there was great uncertainty about the value of M and migration between areas could not be estimated, the working group did not interpret this as underfishing.

The assessments were based on samples taken in the years 1960-73. Mortality estimates do not, therefore, represent 1973 conditions but the level of fishing at some earlier period when the yield was less than 150 000 tons and possibly even less than 100 000 tons, i.e. half the present catch.

The state of exploitation was again assessed in 1977 but the working group did not report in detail the results of the analysis (one yield per recruit curve for each unit). This time, the effect of fishing was evaluated by VPA. Recent mortalities (1973) suggest that fishing is not far from $F_{0.1}$.

Table 5

Approximate distribution of catches (Y) and mortality rates of sprat, herring and cod (Pelagic Working Group, 1977, Demersal Working Group, 1974, 1977)

Subdivision		Sprat			Herring			Cod			Flounder			Plaice		
		Y	M	F	Y	M	F	Y	M	F	Y	M	F	Y	M	F
22-23		8			18	.3	.8	33	.2	.9	3	.2	.8	3	.15	1.3
24		8	.4	.34	56	.3	.8	15	.2	.8	2			1		
25		24	.4	.34	86	.2	.5	85	.3	.7	5	.25	.5			
26		50	.5	.91	50	.2	.5	55	.3	.7	6	.3	.8			
27		5	.2	.19	27	.2	.5	2	.3	.7	1					
28		25	.5	.91	45	.2	.5	10	.3	.7	2	.3	.4			
29		35	.2	.19	45	.2	.5				1					
30					25	.15	.32									
31					8	.15	.32									
32		45	.2	.19	40	.15	.48									
Total		200			400			200			20			4		
average weighted according to catch	M		.35			.21			.28			.26			.15	
	F/Z			.53			.72			.72			.69			.90

Table 6

Food consumption by sprat, herring, cod in the exploited phase

		Sprat	Herring	Cod	Total
Annual average ration per unit biomass, weighted according to biomass per size group		3.966	5.673	3.814	
Biomass, tons x 10^{-3}		647	785	275	1 707
Production, tons x 10^{-3}		377	557	276	1 210
Total food intake	tons x 10^{-3}	2 566	4 453	1 050	8 069
Zooplankton		2 565	2 378		4 943
Fish,			27	656	683
Herring				343	343
Sprat				202	202
Gobies			24	19	43
Sandeel			3	16	19
Other fish				76	76
Benthos			184	350	534
Mysis, etc.		1	1 864	44	1 909
Food conversion, %		14.7	12.5	26.3	15.0

As for herring, an underestimate of the production in the exploited state may be obtained. Table 6 shows the consumption by cod to have been 200 x 10^3 tons. Lishev and Uzars (1967) report the prey on an average to be 0.8 cm smaller than the exploited sprat. In terms of weight, some 16.5% of the sprat consumed are pre-recruits which leaves about 170 x 10^3 tons. Salmon eat roughly 15,000 tons of sprat annually (Thurow, 1966). If all sprat are either caught or eaten by cod or salmon then the total production, P = 385 000 tons and from Y/P = 200/385, the exploitation rate is 0.52 which agrees with the working group value (Table 5). Since there is some natural mortality in addition to that caused by predation by cod and salmon this figure is an over-estimate.

Beverton (1963) has calculated Z = 0.8 for the period 1954-59. The rapid development of the fishery had just started then. Swedish experts found Z = 0.7 for about 1930 when there was virtually no fishing (Pelagic Working Group report 1974). These values for the southern Baltic are much higher than those in the working group report (Table 5). From the average weight, $\bar{w} \approx 10$ g, and Ursin's formula $M \approx 0.46$. This suggests, for the whole region, M > 0.4, and fishing would be below $F_{0.1}$ allowing a gain in yield of some 15%. However, sprat catches are mixed with small herring, the proportions not being known. The potential is, therefore, thought to be near the level of the present catch, i.e. 200 000 tons.

The biomass in the Baltic proper (subdivisions 25-29) may also be evaluated from echo surveys. Falk et al., (1976), Lindquist et al., (1977) have covered about 40% and 60% respectively of the offshore rectangles. From their average densities the biomass for the whole region (210,000 km^2) is estimated (Table 7). Assuming $F_{MAX} = 0.5$ and B_{MAX} = average biomass, $C_{MAX} = 0.5\ \bar{B}$ is calculated, and these values nicely match the actual catches in 1975 and 1976. This again indicates that the fishery presently takes about the potential catch, although F as found by the Pelagic Working Group (Table 5) was 0.6 rather than 0.5.

5.3 Cod

The Demersal Working Group has evaluated the state of exploitation in 1973, 1974 and 1977. It has also used information from reports of individual scientists. The yield curves in the latter report, show for the main stock (east of Bornholm) that fishing (average F for 1972-74 was 0.7) has exceeded the maximum ($F_{MAX} \approx 0.35$). An increase in the average length at first capture from 30 cm to 35 cm would result in a small loss during the first year in the subdivisions east of Bornholm, (-2.5%) and, an immediate gain in subdivision 22. The long-term benefit was shown to be 12% and 32% respectively. A reduction in effort to the level of $F_{0.1}$ in addition to the new l_c would not lead to a gain in yield but it would reduce costs.

Catches during 1967-74 were at the level of 195 000 tons. The recent rise to almost 250 000 tons was probably caused by the very good 1972 year-class. Otherwise the former level might have persisted. Hence, the potential may be about 225 000 tons. One of the major problems in the assessments of cod east of Bornholm is a possible error in basic data because of difficulties in ageing. Frequently, annuli are hardly or only faintly visible. Their identification so far has not been done systematically. Comparative readings show reasonable agreement in age interpretation but trends in errors, if any, are not known. The possible effect of wrong ageing on the assessment cannot, therefore, be evaluated.

5.4 Flatfish

Flounder is the species of major importance among flatfish. Yield per-recruit curves were given in the 1974 report of the Demersal Working Group. The fishery was shown to be near the maximum yield from the Gotland and Bornholm stocks. It exceeded the level of effort giving the highest yield in the Gdansk area (26) and in the Belt Sea (Saeger, 1974). Less fishing in these areas would reduce costs but would not give a much higher yield. An increase of l_c from 21 to 27 cm, on the other hand, would produce a gain of 10% to 17%. Therefore, the working group recommended increasing the average length at first entry to the fishery.

Table 7

Biomass of sprat in subdivisions 25-29 as estimated from echo-integrating surveys, biomass and catch in tons x 10^{-3}

Date		Author	Average density tons/m^2	Biomass B	Average $\bar{B}$	F Max	C Max	Actual catch	Year
May	1975	Falk et al., 1976	8.27	506					
April-June	1976	Lindquist et al., 1977	3.31	203	355	0.5	177	165	1975
Jan.-Feb.	1977	Lindquist et al., 1977	5.06	310	256		128	136	1976

However, much of the flounder is taken in the fishery on spawning cod and flounder. The length at first capture there is not at present controlled by the mesh size but by the average length at maturity which is greater than 27 cm. A gain in yield is to be expected, therefore, by increasing mesh size in the special fishery directed to flounder. This is assumed to produce half the catch in the subdivisions concerned. However, data on landings are uncertain. Flounder caught in the cod fishery are discarded by fishermen of some of the Baltic countries. Losses may occur to the fish released as a result of injury in the trawl and exposure on deck before being liberated. De Veen et al., (1975) found, in preliminary observations, that mortality in plaice from towing and exposure on deck was rather high (> 50%). Table 3 suggests that the total catch is 25 000 tons rather than 15 000 tons. Hence, total losses from fishing might have been some 20 000 tons. An increase in l_c could produce 2 000 tons so that the potential may be 22 000 tons.

The main catches of plaice are taken in the Belt Sea (subdivision 22). This fishery is greatly overexploiting the stock (F = 1.35), and a proper reduction of fishing effort could increase the yield by nearly 20%. Plaice like flounder is largely taken in a mixed fishery and the full gain might not be attainable in practice. The likely increase is perhaps less than 10%.

One has also to consider that flatfish statistics broken down by species are not very reliable. Plaice and flounder together may give a more realistic picture and the potential for both species may be 27 000 tons.

Dab hardly enters the Baltic proper and is largely confined to the Belt Sea. The published catch data are underestimates since a part of the catch is processed to fish meal or used as food for mink and not classified as dab. The species is caught in the mixed fishery all year. Mortality is high. The overall mean Z in the Belt Sea, for ages 4-8, was estimated at 1.37 (H. Knudsen, 1973), i.e. in the same range as for plaice and flounder in the Belt Sea. This suggests that the stock is fully exploited. Any gain that might be obtained by proper management is not likely to be, or not fully, reflected in the statistics.

5.5 Other resources

Little is known of other species which so far have been of little commercial importance. Mention will be made of these in the order they are listed in Bulletin Statistique.

No information is at hand on the status of the stocks of freshwater species, and the potential is assumed to be at the present level of the catch. The ICES Working Group on Stocks of the European Eel (Eel Working Group) was recently established. Data presently available did not permit assessments. The catches of the main contributors to the total yield, Denmark and Sweden, show a decline since 1960. This is believed to be due to a corresponding decrease in density (Eel Working Group, 1975).

It has been shown that a greater mesh size in the offshore fishery for salmon would result in a long-term gain in catches at the proper level of effort (Thurow, 1972). Nothing is known about the other salmonids.

Whiting is caught in a mixed fishery, mainly in the Belt Sea. An increase of the mesh size in the cod fishery, as recommended, is likely to result in a decrease of the catch of this small gadoid fish. Rockling is a by-catch in the cod fishery. If extended to the whole Baltic proper, the figures in Table 3 suggest that a catch of 1 000 to 2 000 tons of rockling is taken at present.

Sandeel does not enter the tables of Bulletin Statistique. Table 6 shows, however, that some 19 000 tons are eaten annually by herring and, in particular, by cod. A catch of this size seems appropriate. The entries in Table 4 on eel-pout (Zoarces), Atlantic gobies, and sticklebacks are all reported from the U.S.S.R. These statistics are thought to be incomplete. Eel-pout and four-horned sculpin, next to herring, are the most important fishes in the trawl fishery (20-50 m) of the Askö area, south of Stockholm, in subdivision 27 (Aneer, 1975). Eel-pout is found in the whole Baltic, and the catch could, therefore, at least be

doubled. Fishing with drop-traps in the Askö area showed two species of gobies to have a density of 1.0 g m^{-2} (Aneer, 1977). They inhabit the greater part of the Baltic Sea which suggests a biomass of the order of 100 x 10^3 tons. Since the life-span is less than two years, the production is higher than half the biomass. Cod and herring consume 43 000 tons of gobies annually (Table 6). A potential catch of some 30 000 tons seems realistic. Sticklebacks represented 55% of the catch in numbers obtained by seine in inshore waters of the Gulf of Finland. The bulk of the catch consisted of small fish (Lemmytyinen and Mankki, 1975). The density of sticklebacks in the Askö area was about 0.9 g m^{-2} (Aneer, 1977). These fish occur throughout the Baltic, and a catch of 30 000 tons, as for gobies, seems possible.

A considerable proportion of the unsorted and unidentified fishes (Table 4) is believed to be herring, sprat and to a lesser extent cod. This category will, therefore, be kept for summing up to the total potential in the Baltic.

Blue mussels are harvested from limited grounds in the Belt Sea.

5.6 Production of zooplankton, benthos and fish

The consumption and conversion of food by sprat, herring and cod in the exploited phase are shown in Table 6. The contribution of different food types to the total consumption of herring and sprat is taken from Zalachowski et al., (1976). Table 6 suggests that sprat production almost entirely results from plankton. On the assumption that the different food types contribute to the herring production according to their weight, zooplankton consumption results in 300 x 10^3 tons of herring so that the total production of herring and sprat from zooplankton is 673 x 10^3 tons. Table 1 gives 5.5 million tons carbon from zooplankton. With 10% carbon in fish, this gives an efficiency of 1.2% from zooplankton to fish. The inclusion of the production of unexploited fish, and of herring and sprat in the pre-exploited phase would not change the order of the efficiency estimate.

There is some evidence that much of the energy from plankton is recycled without having passed the fish. Sjöblom (1966) reported that there seem to be no fish over the deep areas in the Gulf of Bothnia and Finland. This is reflected in Table 1 where the catch per unit area is shown to be extremely low in the Gulf of Bothnia. With the exception of the southern Baltic herring may tend to keep inshore, and thus not utilize the offshore production of zooplankton. Lindquist et al., (pers.comm.), when applying the echo-integrating technique, found a very low biomass in the offshore regions of the Baltic proper. The preliminary results are 280 x 10^3 tons in April to June 1976 and 140 x 10^3 tons in January/February 1977. This is to be compared with catches of 265 000 tons and 246 000 tons taken in 1975 and 1976 respectively in this area.

Another efficiency estimate evolves from the specific feeding behaviour of sprat and herring. Zalachowski et al., (1976) found Temora longocornis and Pseudocalanus elongatus to contribute 81% and 89% to the zooplankton diet of sprat and herring respectively. Temora may be either herbivorous or carnivorous (Martens, 1976). Pseudocalanus permanently inhabiting cold water layers below the thermocline (Mankowski, 1959) may feed, apart from particulate organic matter, on species exhibiting daily vertical migrations. Should the plankters in question be entirely carnivorous the clupeids would feed on the tertiary level. For the Kiel Bay Martens (1976) assessed the tertiary level to be the fraction 0.133 of the total zooplankton production.

From Table 1 we then have 732 000 tons of carbon. With 10% carbon in fish (67 300 tons) we have an efficiency of 9.2%.

Production estimates of benthos are available for the Askö area (south of Stockholm) and Kiel Bay, both regions being rather small and shallow. P/B for Diastylis equals 2 (from data of Arntz, 1971). Ankar and Elmgren (1976) found 2.8 for Pontoporeia. Their suggestion for the bottom fauna of the Askö area is 1.2 The production in the whole Baltic is not likely to greatly differ from the biomass as much of the benthos consists of the molluscs Mytilus and Macoma. On the assumption that the conversion rate of benthos to fish is the same as the overall rate for each species (Table 6) only 115 x 10^3 tons of herring and cod of commercial

size are produced from predation on benthic animals. Some 35 000 tons of flatfish production may be added to this figure. This gives an efficiency of 1.6% from benthos to fish. Clearly, cod and flatfish in the pre-exploited state as well as other species not fished upon feed on benthos. It was, on the other hand, shown that cod does not feed on molluscs except in the Belt Sea (Zalachowski, et al., 1976; Strzyzewska, 1962). Also, the polychaete Scoloplos, which contributes as much as 90% to the benthos biomass in the deeper regions of the Bornholm basin (Leppäkoski, 1969, 1975), was not found in the stomachs of cod. Estimates of fish production from benthos are, therefore, not possible without detailed information.

It is also important that Mysis mixta contributes largely to the diet of herring. No estimates of biomass or production of this species are available as it did not figure in either plankton or benthos.

5.7 Potential catches

The foregoing sections suggest that some demersal percomorphs are the only resource not fully exploited. The relevant species are all of little commercial value but are preyed upon to some extent by cod, herring and salmon. Their full exploitation will, therefore, adversely affect other stocks although it is not known to what extent.

No assessments are available for freshwater species and most of the salmonids but their share in the total catch is low, and improvement of the statistics might cost more than could be gained by higher exploitation or proper adjustment of the fishery. All other species are fully exploited and gains in yield can only be expected from proper management.

Finally, flatfish show their potential to be much higher than the present catch (Table 4). However, this is for the most part due to incomplete records of catches and of discards at sea.

In summary, proper management of presently exploited species and improvement in collecting data on landings will result in a catch of 1 million tons. This figure may be exceeded by a few thousand tons when the exploitation of demersal percomorphs is increased.

6. PROSPECTIVES FOR ACTUAL DEVELOPMENT

6.1 Unexploited resources

Table 4 shows few species for which the potential is likely not to have been reached at present. Sandeel is preyed upon by cod, herring and salmon. On a small scale it is taken by beach seines to be used as bait. Before the war catches were taken on sandy bottom along the southern shores. The otter trawl might yield some catches there and possibly elsewhere on appropriate grounds. The fish is not used for human consumption. Fishing for industrial purposes, on the other hand, is not likely to be of great benefit.

Eel-pout is a tasty fish, and the stock is likely to yield a higher catch than at present. This will have to be obtained by fixed gear or something similar.

Garfish is caught by fixed gear on the spawning ground. A reasonable increase in landings can probably be obtained although the market for human consumption is limited in some countries.

A considerable rise in the exploitation of other percomorphs such as sticklebacks and gobies seems possible. The catch will have to be processed to oil and fish meal, and it is doubtful whether a fishery would pay.

Except for eel-pout the species mentioned are all preyed upon by cod, salmon and somewhat less, by herring. An increase in exploitation may therefore shift the cod more to its main diet, e.g., sprat and herring.

6.2 Management of principal stocks

Measures currently in force to control size at first capture and effort are shown in Table 8. Additional means of protecting young clupeids are being actively considered by the Commission. These range from minimum landing sizes to separate TACs for young and adult herring. A ban on industrial fishing was also advocated by some countries. This measure, if strictly enforced, would clearly enable a much better management of the clupeid stocks than is possible at present.

A better adjustment of the average size at first capture of cod is also being considered by IBSFC. At the request of the Commission this was followed up by the Demersal Working Group (1977) and a minimum landing size of 35 cm as well as a minimum mesh size of 110 mm (stretched) was recommended.

The closed seasons for flounder and plaice are not fully effective. Both species are incidentally caught in the cod fishery (section 4.4). A quota allocation for the stocks in subdivisions 22 and 26, which are overfished, would likewise be affected by the mixed fishery.

A recommendation on joint enforcement of fisheries regulations in the Baltic came into force in 1977.

6.3 Future studies

The foregoing sections have revealed some shortcomings which are summarized here.

Estimates of fish production cannot be verified at present from zooplankton and benthos production (section 4.6). As far as the whole Baltic is concerned the problems are that production at the secondary and tertiary levels is either unknown (benthos) or uncertain (plankton), and that information on the contribution of those species consumed by fish is scarce. Sampling in time and space would have to allow for these essentials.

Zooplankton biomass exhibits several peaks a year and samples should be taken, therefore every other week. Variation in space is not known and will have to be investigated before the number of stations is determined, the ICES system of subdivisions being the basis.

Benthos sampling should be stratified according to depth layers, the surface area of which is available. Frequency of sampling in time must permit mortality estimates. Breakdown to species fed upon by fish is necessary.

Food requirements and food composition of fish permit independent estimates of the utilization of trophic levels and of production. The extension of investigations to all Baltic regions and to all major species would be helpful. Specifications of food items as to their length and weight composition should be given.

Assessments of exploited stocks largely depend on the quality of basic data. Sampling of the catch should reveal the true age-composition. It should detect any admixture with other species, i.e., herring in sprat landings.

In general, measures of reliability, wherever possible, should be reported. Lack of statistical parameters is one of the great shortcomings in today's reports from the Baltic.

Table 8

Management measures currently in force in the Baltic

	Minimum landing size, cm	Mesh opening (stretched) mm	Undersized by-catch in % of total catch	TAC 1977, tons x 10^{-3}	TAC 1978, tons x 10^{-3}	Closed season, months
Herring		16-32 R		422	444	
Sprat		16		275	184	
Cod	30	90	5	185	174	
Flounder	18-25 R	70-90 R	0			II-IV, V, VI, D
Plaice	18-25 R	70-90 R	0			II-IV, V, VI, D
Turbot	30		0			VI-VII
Brill	30		0			VI-VII
Sturgeon						I-VII
Eel	35		0			
Salmon	60	157 S 19 H	0			VI-VIII I XII/I I

D: differential seasons for subdivisions, duration increases south to north, in subdivision 22 for females only
H: hook size between point and shaft
L: limited to 1 June - 25 August and 20 December - 10 January
R: regional differences increase north to south
S: synthetic fibre, 165 mm natural fibres

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